Effect of Refinement and Modification Molding by Tow Process of Cast Aluminum-Silicon Alloys

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Abstract— **The solidification process significantly affects the microstructure and mechanical properties of the aluminum-silicon alloys. This article discusses the effect treatment of the liquid metal, namely the refining and the modification on the mechanical properties of a hypereutectic silicon aluminum alloy, molded by two molding processes. Sand mold casting and shell. The study shows that the hardness increases for the two treatments and in the two molding processes. On the other hand, the refining treatment has a reciprocal influence on the mechanical properties. However the modification slightly improves the mechanical properties**

Keywords: Solidification, refinement, process, cast; molding.

I.INTRODUCTION

Al–Si alloys are most widely used aluminum alloys due to their castability, high strength to weight ratio, corrosion resistance,…etc [1,2].This fosters use is to reduce cars and aeronautic equipment's weight and other automotive applications [3,7]. Grain refinement has regarded as one of the most effective techniques to enhance the mechanical properties of metal castings and to improve the formability of metal ingots [8–10]. The currently available techniques for grain refinement of cast metals include vibration and stirring [11, 12], rapid solidification [13] and inoculation treatment [14]. For solid metals, severe plastic deformation is generally used to refine the grains to micrometer and even nanometer scales [15,16]. In industrial production, inoculation treatment through addition of proper grain refiner is widely used in metal castings [17]. For example, TiB2 and Al3Ti are effective grain refiners to promote heterogeneous nucleation for cast aluminum alloys [18,19]. In This work we are study the effect of inoculation and modification using tow process send shell casting.

II. EXPERIMENTAL PROCEDURE

The objective of our study is therefore to be able to control the microstructure, using liquid metal treatment in order to determine the most suitable treatment and casting process for obtaining high performance, hypersilicon aluminum parts. For this, we will have to carry out a series of experiments such as tensile tests, hardness tests, cooling rate measurements, ...

The table below presents the composition of metal using:

TABLE1: AVERAGE VALUES OF SOME THERMOMECHANICAL PROPERTIES OF ALSI17CU4 ALLOY.

Element	Si	Cr	Fe	Ni	Cu	Zn	Mn	Al
Average content wt%	16,135	0,035	0,453	0,027	6,580	0,186	0,203	Bal

A. Production of test specimens

We cast different specimens allowing us to subsequently perform the various tests, which are a micrographic analysis, the recording of thermal curves, tensile tests, hardness tests, chemical analysis and measurement of the porosity rate.

B.Material available

To make these specimens, we heated the aluminum hypereutectic AlSi17Cu4 alloy in induction furnace. During all of our castings, the alloy was heater in the same furnace to a temperature of 650 ° C without heating any other metal. We have cast different specimens allowing us subsequently perform the various tests, which are a micrographic analysis, the recording of thermal curves, tensile tests, and hardness tests.

The objective of this study is a comparative the manufacturing of a hypereutectic AlSi17Cu4 sample using tow process.

FIG1: METAL HEATING FURNACE

The test pieces are cast in sand molds (produced by the PEP SET process) comprising five test pieces and in a shell mold Comprising four test pieces.

To make the molds, we mixed the sand with 0.5% phenolic resin relative to the sand mass, 4% catalyst and finally 0.5% isocyanate resin.

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FIG 2: SAND MOLD

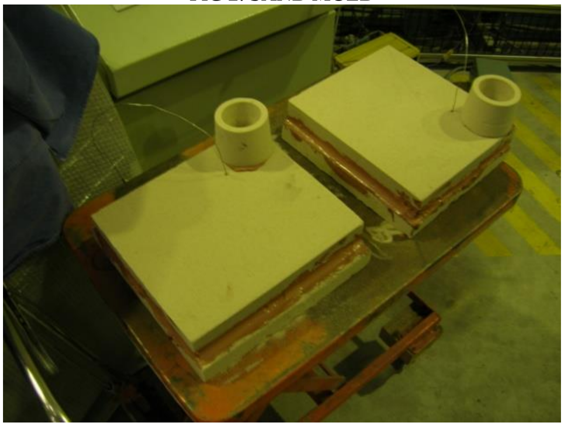


FIG 3: SHELL MOLD

The tests carried out are on two treatments, the first Being A refining treatment. The second is a modification treatment.

C. Refining

For the refining treatment, we used as an additive element ALUFLUX B (Titanium and Boron) in the form of 200g pellets.

TABLE 2: PERCENTAGE OF REFINER USED

% of treatment	*Number of samples*
0.5% of the metal mass in the furnace	1
0.8% of the metal mass in the furnace	2
1.2% of the metal mass in the furnace	3

D. Modification

For the modification treatment, we used as an additive Element SIMODAL 77 (Sodium), in the form of a 200g tablet, 0.2%.

TABLE 3: PERCENTAGE OF MODIFIER USED

% of treatment	*Number of samples*
0.3% of the mass in the furnace;	1
0.5% of the mass in the furnace;	2
1.0% of the mass in the furnace.	3

E. Degassing treatment

For the degassing treatment, we used as an additive element DEGAZER 701 SM (Nitrogen and without Sodium), in the form of a 200g pellet, 0.5%.

III. RESULTS AND DISCUSSION:

To study the effect of refining and modification treatments on the solidification parameters. We have produced test specimens by which to measure, hardness, porosity, and microstructure tests using the two treatments for both sand and shell molding processes.

a- Hardness

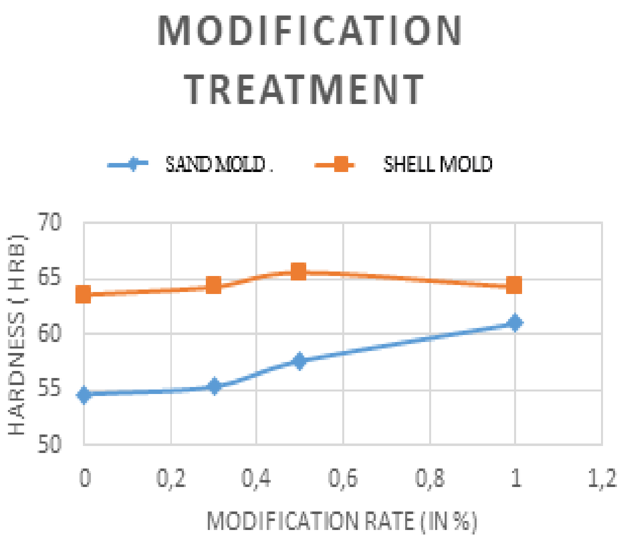
At this level, we will measure the hardness of the different samples that we have taken to compare the influence of the different treatments. As these hardness measurements were performed on the aluminum alloy AlSi17, we used the Rockwell ball hardness for our tests. The values given below are average values calculated from the three most significant values out of five measurements for each sample. The table below represents the results obtained

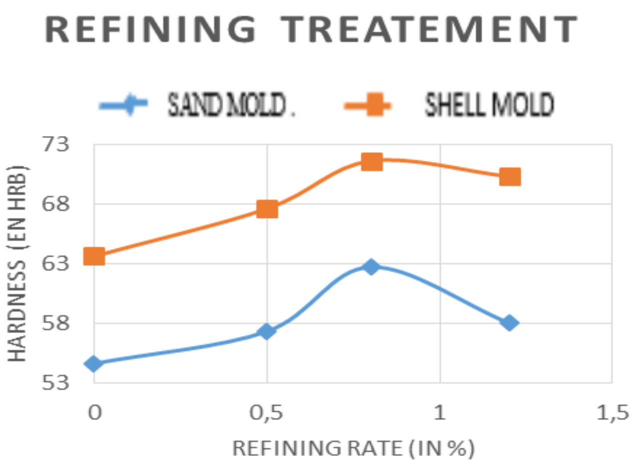
TABLE 4: THE AVERAGE HARDNESS FOR EACH TREATMENT

Sample	***Rockwell hardness ball (HRB) Shell***	***Rockwell hardness ball (HRB) Sand***
Without treatment	63,6	54,6
Modification of 0,3%	64,3	55,3
Modification of 0,5%	65,6	57,6
Modification of 1,0%	64,3	61
Refining 0,5%	67,6	57,3
Refining 0,8%	71,6	62,7
Refining 1,2%	70,3	58

Two curves below reflect the variations in hardness depending on the treatment used:

FIG 4: CURVES OF VARIATION OF HARDNESS AS A FUNCTION OF REFINING AND MODIFYING RATE FOR THE TWO PROCESSES.





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From the results obtained it can be deduced that the refining and the modification having a significant effect on the hardness. such that the optimum rate for modification is about 0.5% and that for refining is 0.8%. However, these results must also be coupled with those obtained during micrograph studies since the smaller the size of the primary silicon grains, the greater the hardness.

b- Mechanical tests (Rm, E)

The various cast specimens will serve us mainly to determine the mechanical characteristics of this alloy. For this, we carried out tensile tests. Then, in the analysis of the results, we will only consider the test pieces giving consistent data, and we will take an average of these values, considering the standard deviation and the dispersion of the measurements.

TABLE 4: PERCENTAGE OF MODIFIER AND REFINING USED

Reference sand

Rate	E (Gpa)	R_m (Mpa)	A (%)
0,0%	78	156	0,15

Modification_Sand

Rate	E (Gpa)	R_m (Mpa)	A (%)
0,3%	71	160	0,21
0,5%	72,00	159	0,22
1,0%	77	150	0,13

Refining Sand _

Rate	E (Gpa)	R_m (Mpa)	A (%)
0,5%	74	118	0,04
0,8%	75	95	0,03
1,2%	73	108	0,05

Reference shell

Rate	E (Gpa)	R_m (Mpa)	A (%)
0,0%	61	160	0,16

Modification shell

Rate	E (Gpa)	R_m (Mpa)	A (%)
0,3%	59	140	0,17
0,5%	61	151	0,17
1,0%	60	153	0,19

Refining shell

Rate	E (Gpa)	R_m (Mpa)	A (%)
0,5%	60	118	0,06
0,8%	62	114	0,03
1,2%	62	108	0,03

The blue tables serve as references, that is to say, they indicate the characteristics of the test pieces without treatment. We recall that "A (%)" represents the permanent elongation of the test piece under the stress Rm. To compare these results and to be able to analyze them, let us draw up the following graphs, that is to say:

- Young's modulus: E (GPa)
- Tensile strength according to the different treatment rates (refining and modification): Rm (Mpa)
- Permanent elongation: A (%)

FIG 5 CURVES OF VARIATION YOUNG'S MODULUS, TENSILE STRENGTH AND ELONGATION AS A FUNCTION OF REFINING FOR USING SAND MOLD .

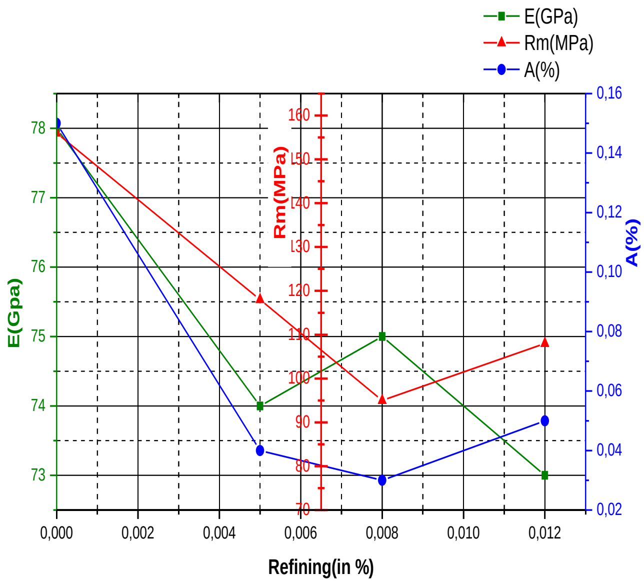


FIG 6 CURVES OF VARIATION YOUNG'S MODULUS, TENSILE STRENGTH AND ELONGATION AS A FUNCTION OF MODOFICATION FOR USING SAND MOLD .

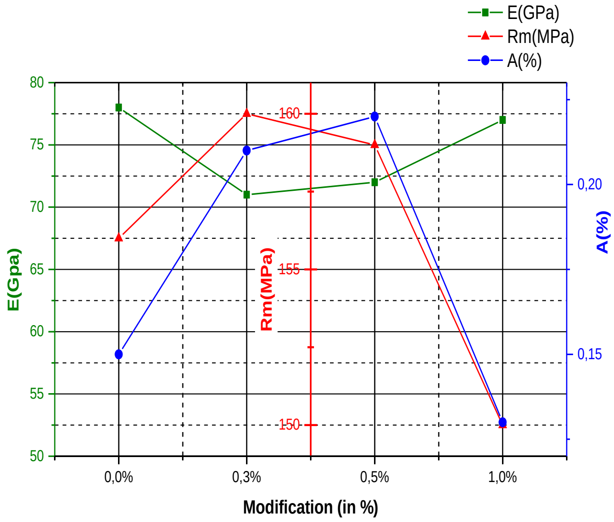
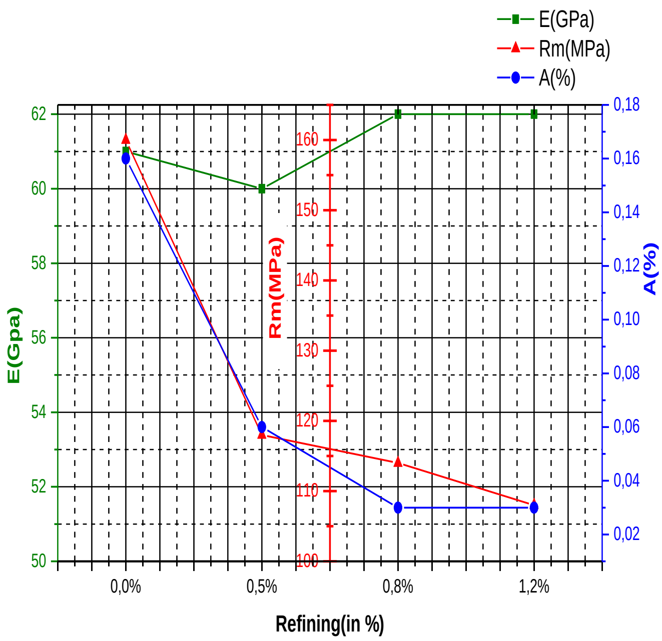
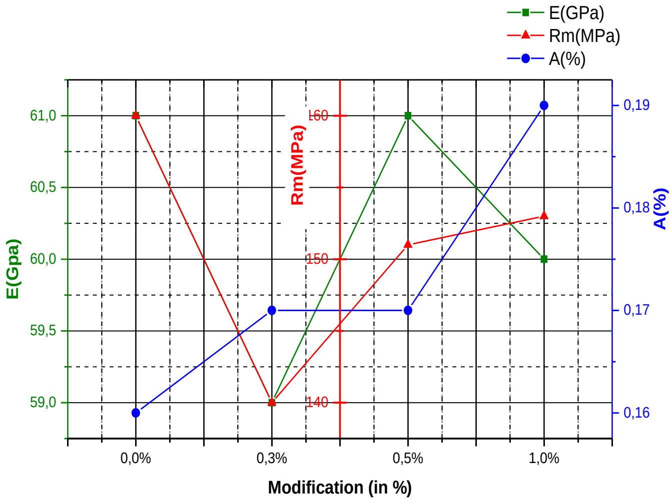


FIG 7: CURVES OF VARIATION YOUNG'S MODULUS, TENSILE STRENGTH AND ELONGATION AS A FUNCTION OF REFINING FOR USING SHELL MOLD.



With regard to permanent elongation of test pieces, the previous graph reveals some trends. First, the refining treatment does not promote strong permanent elongation, whether in shell casting or sand molding. However, we see a minimum reached for 0.6% ripening.

FIG 8: CURVES OF VARIATION YOUNG'S MODULUS, TENSILE STRENGTH AND ELONGATION AS A FUNCTION OF MODOFICATION FOR USING SAND MOLD



With regard to permanent elongation of test sample, the previous graph reveals some trends. First, the refining treatment does not promote strong permanent elongation, whether in shell casting or sand molding. However, we see a minimum reached for 0.6% ripening.

As regards the modification, the specimens cast in shells exhibit an increasingly important permanent elongation as the rate of modifier increases. Contrary to this behavior, the test pieces cast in a sand mold make it possible to demonstrate an optimum point of maximum permanent elongation, reached for a modifying rate of 0.5%. We can explain the phenomenon of increased elongation in the case of a modification treatment through the consequence of the modifier on the microstructure of the material. Indeed, as explained in the section presenting the modification, this treatment of the liquid metal will, among other things, modify the eutectic (initially as a needle) to result in a globular morphology. However, this morphology offers more ductility to the material, hence an increase in the permanent elongation of the modified specimens.

IV. CONCLUSION

According to the work carried out, it was possible to establish optimal rates, namely a rate of 0.5% of modifying agent and 0.8% of refining agent. We have noticed the overall degrading effects of the refining on the mechanical strengths and the microstructure. On the other hand, the modifying agent proves to be effective because from the rate of 0.5%, we obtain very good results.

In a more general way, we were able to determine the effects of refining and modification treatments on a hypersilicate aluminum alloy which was relatively little known until then.

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